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Lifetime risk of pregnancy-related death among Zambian women: district-level estimates from the 2010 census

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Abstract The aim of this study was to examine district differentials in the lifetime risk of pregnancy-related death among females aged 15–49 in Zambia. We used data on household deaths collected in the 2010 census to estimate the lifetime risk of pregnancy-related death among females in Zambia. Using all-cause age-specific death rates, we generated female life tables for 74 districts and estimated person-years of exposure to all-cause mortality at each age. We then applied age-specific pregnancy-related mortality rates to the person-years of exposure to obtain estimates of adult lifetime risk that took account of competing causes of death. We used the ArcGIS software to analyse clustering and the spatial distribution of risk. A female aged 15 in Zambia had a 3.7 % chance of dying a pregnancy-related death before the age of 50. At district level, the lifetime risk ranged from 1.7 to 7.7 %. The Global Moran's I was 0.452 (*z-score* 5.8, *p* value <0.01), indicating clustering of districts with similar risk levels of pregnancy-related mortality. Clustering of high-risk districts was found in Western province while clustering of low risk districts was found in Lusaka and Muchinga provinces. The level of adult lifetime risk was more positively associated with pregnancy-related mortality than with fertility. Females in Zambia have a high lifetime risk of pregnancy-related death overall but this risk varies greatly across the different districts of the country. The observed diversity is larger than when merely studying differences between provinces and is

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only weakly linked to differences in fertility levels. The identification of districts with varying levels of risk should enable evidence-based and focused delivery of maternal health services in districts where risk of death from maternal causes is greatest.

Keywords Pregnancy-related death · Lifetime risk · Census · Zambia · Maternal mortality

Background

An estimated 289,000 women globally died of maternal causes in 2013, with 62 % of these deaths occurring in sub-Saharan Africa (World Health Organisation et al. 2014). Studies show that the main direct obstetric causes of maternal deaths are haemorrhage, hypertensive disorders of pregnancy, sepsis and complications of abortion (Ronsmans et al. 2006; Say et al. 2014). Although many women die annually from maternal causes, such deaths are preventable with known interventions (Campbell and Graham 2006; Ronsmans et al. 2006). To reduce maternal mortality, interventions must be focused in areas where women face the greatest risk (Ronsmans et al. 2006).

The level of maternal mortality in a population is considered to be a result of a combination of the risk of death during pregnancy or childbirth and the level of fertility (World Health Organisation et al. 2014). The adult lifetime risk (ALTR) of maternal mortality is therefore an important indicator of the reproductive health status of the population as it measures the cumulative loss of adult female life due to maternal causes (Wilmoth 2009). While the maternal mortality ratio (MMRatio) is an important indicator of the current magnitude of mortality due to maternal causes, the ALTR gives an indication of the number of deaths that could potentially be averted (Graham et al. 2007).

Several methods are used to estimate the ALTR, mostly determined by the type and source of available data. The ideal method requires the use of age-specific data on maternal deaths and the population at risk of such deaths (Wilmoth 2009). Lack of age-specific data prevents the appropriate estimation of the ALTR for subnational levels. Therefore more indirect methods using the maternal mortality rate (MMR) and the MMRatio are often used (Graham et al. 2007; Wilmoth 2009; World Health Organisation et al. 2014). Since actual maternal deaths are challenging to measure, especially in settings with incomplete vital registration systems, pregnancy-related deaths are often used as a proxy for maternal deaths in the estimation of ALTR.

The ALTR varies greatly across countries. In 2010, the United Nations (UN) estimated that globally, 1 in every 108 women died of maternal causes during her reproductive life course, and the risk was much higher in sub-Saharan Africa where 1 in every 37 women died from such a cause (World Health Organisation et al. 2012). Within sub-Saharan Africa, the ALTR ranged from 1 in every 15 women in the Republic of Chad to 1 in every 1000 women in Mauritius (World Health Organisation et al. 2012). The UN estimate for Zambia for the year 2010 was also

substantial: one woman in every 37 women, or 2.7 %, died of maternal causes during her reproductive life course (World Health Organisation et al. 2012).

Just as the ALTR varies across countries, in-country variations also exist, reflecting differences in the determinants of risks faced by women during pregnancy and childbirth in the different regions. Studies examining geographical differences in ALTR, beyond the urban–rural differences, are rare, however. For Zambia, only two studies so far, conducted in two different provinces in the late 1990s, provide an indication of subnational estimates of the ALTR. Both studies used the sisterhood method and therefore identified pregnancy-related deaths of females of reproductive age. The study conducted in Kalabo in the Western province estimated the ALTR to be 8.5 % (Vork et al. 1997), while the study covering two districts in Northern province (Kasama and Kaputa districts) estimated ALTRs of 5.4 and 11.0 %, respectively (Le Bacq and Rietsema 1997). None of the studies took competing causes of adult female deaths into account in generating their estimates of ALTR although competing causes can be particularly important in settings where adult female mortality from non-maternal causes is also high, as was the case in Zambia at the time of the two studies.

In October 2010, Zambia conducted a national population census in which information on pregnancy-related deaths was collected (Central Statistical Office 2012a). This was the first time that the country had included such information in a census and it followed the recommendation by the UN to consider maternal mortality a core topic in the 2010 round of national population censuses (United Nations Statistics Division 2008). This provided a unique opportunity to study pregnancy-related mortality at a subnational level, including the estimation of the ALTR using age-specific data and taking into account other causes of death among reproductive-age women. No previous studies in Zambia have done this.

In this paper, alongside our examination of the district differentials in lifetime risk of pregnancy-related death among females aged 15 in Zambia, we also assess the associations of the prevailing level of lifetime risk with both fertility and pregnancy-related mortality.

Methods

Setting

For our study on district differentials in lifetime risk of pregnancy-related deaths among women in Zambia, we used the Zambia 2010 census. The Zambia 2010 census was conducted in October 2010 using the traditional approach of door-to-door canvassing of all households in Zambia by about 33,000 enumerators, supervisors and other census field staff (Central Statistical Office 2012a). At the time of the census, the country had 74 districts and nine provinces. A tenth province was created soon after the census, and geographic data was re-coded to enable the generation of estimates for ten provinces namely; Central, Copperbelt, Eastern, Luapula, Lusaka, Muchinga, Northern, North Western, Southern and Western provinces (Central Statistical Office 2012a). This study made use of data for the 74

districts and 10 provinces. See the “[Appendix](#)” for a map of Zambia showing both provinces and districts.

Data on pregnancy-related deaths

The World Health Organization (WHO) identifies a pregnancy-related death as a “death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death” (World Health Organization 2009). The Zambia 2010 census collected information on deaths during the period 12 months prior to the census and for households reporting deaths of females aged 12–49, inquiry was made to ascertain the death relative to pregnancy; “Did the death occur while pregnant?” If the answer was “no” to this question, the census household respondent was asked: “Did the death occur during childbirth?” and if the answer was “no” to this too, a third question was posed: “Did the death occur during the 6 week period following the end of pregnancy, irrespective of the way the pregnancy ended?” (Central Statistical Office 2012a). For our analysis, we defined pregnancy-related deaths as captured in the census i.e. any reported deaths of women during pregnancy, childbirth or within the six-week period after termination of pregnancy. Due to the small number of pregnancy-related deaths in the age group 12–14, our analysis focused on reported deaths of women aged 15–49. Since methods for evaluating the completeness of pregnancy-related deaths recorded in a census are not currently available (Hill et al. 2011; Hill and Stanton 2011), we made no adjustment to the pregnancy-related deaths. However, we assessed the age pattern and the proportional contribution of pregnancy-related deaths to the total number of deaths of reproductive age women as a check for plausibility (see also Banda et al. 2015).

We evaluated the completeness of all deaths reported by households in the census using an established method, the *Brass Growth Balance* method (United Nations 1983). Although the method assumes a stable and closed population, its application provided plausible estimates of adjusted mortality rates, which proved to be more realistic than the crude estimates (Banda et al. 2015). It was also convenient since it does not require the use of two censuses, as is the case for the *General Growth Balance* method.

Data on fertility

For us to assess the association between lifetime risk of pregnancy-related mortality and fertility, we also used census information on live births to women aged 15–49 in the 12 months preceding the census and children ever born (CEB) to women aged 15 years and older. Since live births are usually underreported in censuses, we used the *Brass PF Ratio* method (United Nations 1983) to evaluate completeness of reported live births, and to adjust the crude age-specific fertility rates (ASFRs). We used the average of the PF ratios for age groups 20–24, 25–29 and 30–34 in determining the adjustment factor for the reported number of live births. In order to compute appropriate ASFRs corrected for age misreporting by women reporting births in the census, we evaluated the census age distributions using the age-sex

accuracy index (ASAI) (Shryock and Siegel 2004), and adjusted the age distribution for age heaping/digit preference using the *Arriaga Technique* (U.S. Census Bureau 1994), a mild smoothing method that maintains the population totals. The adjusted ASFRs were used in estimating the adjusted total fertility rate (TFR) and the adjusted total number of live births, used as denominator in the estimation of the pregnancy-related mortality ratio (PRMRatio).

Estimation of adult lifetime risk of pregnancy-related death (ALTR)

The adult lifetime risk of a maternal death is defined as the probability that a female survivor from birth to age 15, exposed to the observed age-specific maternal mortality rates during her reproductive life course, will die from maternal causes before age 50, taking account of competing causes of death (Wilmoth 2009). We applied this definition in our analysis of the risk of pregnancy-related death by replacing “maternal” in the definition with “pregnancy-related”. We used age-specific death rates to generate period life tables for each of the 74 districts. Using population numbers and pregnancy-related deaths, we estimated age-specific pregnancy-related mortality rates (PRMRs) for each 5-year age group between age 15 and 50. From the period life tables, we estimated the number of person-years lived by a female aged 15 at each age, exposed to all-cause mortality, during her reproductive life course. We then estimated the ALTR by applying the age-specific PRMRs to the exposure (person-years) to all-cause mortality at each age, summed up over the entire reproductive age group, 15–49. In so doing, the estimate of ALTR takes into account competing causes of adult female deaths (Wilmoth 2009). We assumed that age-specific fertility and mortality rates prevailing at the time of the census would remain constant throughout the female reproductive life course.

Analysis

We mapped the spatial distribution of ALTR at district level using ArcGIS software version 10.2 (Environmental Systems Research Institute 2013) and tested for clustering using the spatial statistics tool, Global Moran’s I. The Global Moran’s I measures the spatial distribution of feature locations (in this case, districts represented as polygons with x–y coordinates) and associated attributes (the ALTR) by evaluating whether the pattern expressed is clustered, dispersed, or random (Environmental Systems Research Institute 2013). The Global Moran’s I tool computes an *index* and *expected value* using information about the feature locations and associated attributes. Index values fall between -1.0 and $+1.0$; negative values indicate dispersion, positive values indicate clustering and 0 indicates random spread. The computed *index* and *expected values* are then compared, and a *z-score* for the difference is computed, together with a *p-value* (indicating whether the difference of the two is statistically significant). The null hypothesis for this test is that the attribute (ALTR) is randomly distributed across feature locations (districts), and the value of the *p-value* is used to reject or accept the null hypothesis. We did similar analysis of clustering for the total fertility rate (TFR), proportion of female

Table 1 Adult lifetime risk (ALTR) and other indicators by district, Zambia 2010 census

District name	ALTR (per woman)	PRMR (per 1000 women)	TFR (per woman)	Total population of women aged 15–49	Total number of pregnancy-related deaths	Total number of births to women aged 15–49	PRMRatio (100,000 live births)	Total number of deaths of women aged 15–49	PMFD (%)
Chadiza	0.0291	0.94	7.54	22,230	21	5323	395	139	15.1
Chama	0.0209	0.77	7.75	21,953	17	5471	311	126	13.4
Chavuma	0.0229	0.66	5.95	7525	5	1228	407	49	10.3
Chibombo	0.0355	1.19	6.49	64,121	76	14,066	540	710	10.7
Chiengi	0.0699	2.53	7.57	25,346	64	6528	980	357	17.9
Chililabombwe	0.0337	1.23	4.8	22,730	28	3417	819	243	11.5
Chilubi	0.0765	2.47	7.67	17,030	42	4485	936	151	27.8
Chingola	0.0296	1.01	4.88	54,319	55	7216	762	718	7.7
Chinsali	0.0207	0.70	7.32	30,189	21	7176	293	177	11.8
Chipata	0.0392	1.30	6.14	100,790	131	19,394	675	1026	12.8
Choma	0.0279	0.83	6.64	54,544	45	11,830	380	426	10.6
Chongwe	0.0226	0.75	6.09	41,117	31	8112	382	456	6.8
Gwembe	0.0167	0.62	6.66	11,332	7	2271	308	70	10.0
Ikelenge	0.0219	0.72	6.86	6966	5	1430	350	27	18.5
Isoka	0.017	0.70	6.47	15,678	11	3121	352	97	11.3
Itezhi-tezhi	0.0254	0.93	5.78	13,994	13	2795	465	150	8.7
Kabompo	0.0379	1.25	6.43	19,253	24	3617	663	128	18.8
Kabwe	0.0376	1.24	4.57	52,569	65	6863	947	714	9.1
Kafue	0.0212	0.70	5.11	54,154	38	8554	444	562	6.8
Kalabo	0.0664	2.28	6.15	28,921	66	5994	1101	373	17.7
Kalomo	0.0315	1.05	7.33	54,519	57	13,747	415	317	18.0
Kalulushi	0.0465	1.52	5.38	24,372	37	3654	1012	301	12.3
Kaoma	0.0636	2.27	6.09	40,491	92	7902	1164	598	15.4

Table 1 continued

District name	ALTR (per woman)	PRMR (per 1000 women)	TFR (per woman)	Total population of women aged 15–49	Total number of pregnancy-related deaths	Total number of births to women aged 15–49	PRMRatio (100,000 live births)	Total number of deaths of women aged 15–49	PMFD (%)
Kapiri Mposhi	0.0494	1.73	6.61	54,198	94	11,251	835	623	15.1
Kaputa	0.0622	2.26	7.14	25,218	57	6920	824	263	21.7
Kasama	0.0467	1.49	6.46	50,990	76	10,394	731	456	16.7
Kasempa	0.05	1.57	7.44	14,041	22	3242	679	129	17.1
Katete	0.0281	0.93	6.6	51,851	48	11,227	428	401	12.0
Kawambwa	0.0342	1.30	7.84	28,562	37	6199	597	360	10.3
Kazungula	0.0354	1.11	6.56	21,593	24	4550	527	174	13.8
Kitwe	0.0277	0.94	4.67	134,413	126	18,742	672	1653	7.6
Livingstone	0.0199	0.74	3.93	37,773	28	5040	556	359	7.8
Luangwa	0.0311	1.33	5.32	5253	7	818	856	72	9.7
Luanshya	0.0309	1.01	4.53	39,637	40	4645	861	525	7.6
Lufwanyama	0.056	1.79	7.02	16,234	29	3360	863	178	16.3
Lukulu	0.0488	1.66	6.18	18,675	31	3822	811	209	14.8
Lundazi	0.0449	1.47	7.04	68,826	101	16,303	620	427	23.7
Lusaka	0.0234	0.78	4.42	477,915	375	66,483	564	4532	8.3
Luwingu	0.0464	1.52	6.64	25,738	39	5132	760	222	17.5
Mafinga	0.0353	1.15	7.5	13,915	16	3196	501	94	17.1
Mambwe	0.0394	1.30	6.36	14,651	19	2816	675	163	11.7
Mansa	0.0479	1.72	6.86	48,938	84	10,084	833	639	13.1
Masaiti	0.0447	1.52	6.74	22,320	34	3913	869	283	12.0
Mazabuka	0.033	1.03	5.56	54,202	56	9413	595	471	11.9
Mbala	0.0201	0.66	7.19	42,681	28	9669	290	216	13.0
Milengi	0.0498	1.58	8.34	8852	14	2367	592	72	19.4

Table 1 continued

District name	ALTR (per woman)	PRMR (per 1000 women)	TFR (per woman)	Total population of women aged 15–49	Total number of pregnancy-related deaths	Total number of births to women aged 15–49	PRMRatio (100,000 live births)	Total number of deaths of women aged 15–49	PMFD (%)
Mkushi	0.0368	1.08	6.62	33,475	36	6887	523	242	14.9
Mongu	0.0612	2.37	5.38	40,949	97	7207	1346	859	11.3
Monze	0.0303	0.90	6.78	41,307	37	9361	395	311	11.9
Mpika	0.0505	1.64	6.93	43,379	71	9275	765	425	16.7
Mpongwe	0.0541	1.81	7.07	19,864	36	4727	762	260	13.9
Mporokoso	0.0462	1.45	7.13	20,653	30	4817	623	177	16.9
Mpulungu	0.0411	1.41	7.16	21,223	30	5052	594	165	18.2
Mufulira	0.0295	0.95	4.67	41,170	39	5106	764	486	8.0
Mufumbwe	0.0245	0.77	7.63	11,702	9	2861	315	100	9.0
Mumbwa	0.0475	1.67	6.58	46,588	78	10,092	773	587	13.3
Mungwi	0.0492	1.66	7.72	30,642	51	8081	631	228	22.4
Mwense	0.066	2.19	7.33	26,482	58	5385	1077	274	21.1
Mwimilunga	0.031	1.11	7.63	21,558	24	5090	472	146	16.5
Nakonde	0.0246	0.81	6.25	27,184	22	5873	375	230	9.6
Namwala	0.0393	1.47	6.13	21,145	31	4645	667	222	13.9
Nchelenge	0.0635	2.37	6.93	33,343	79	7467	1058	499	15.8
Ndola	0.0263	0.87	4.78	116,290	101	15,598	648	1551	6.5
Nyimba	0.0446	1.56	6.81	17,978	28	3822	733	288	9.7
Petauke	0.0483	1.67	6.72	66,326	111	14,839	748	780	14.2
Samfya	0.039	1.40	7.35	42,743	60	9012	666	443	13.6
Senanga	0.0575	2.33	6.16	27,498	64	5384	1189	527	12.1
Serenje	0.0488	1.57	7.56	34,946	55	7727	712	408	13.5
Sesheke	0.0341	1.26	6.33	20,703	26	4317	602	254	10.2

Table 1 continued

District name	ALTR (per woman)	PRMR (per 1000 women)	TFR (per woman)	Total population of women aged 15–49	Total number of pregnancy-related deaths	Total number of births to women aged 15–49	PRMRatio (100,000 live births)	Total number of deaths of women aged 15–49	PMFD (%)
Shang'ombo	0.061	2.08	6.26	19,713	41	3801	1079	190	21.6
Siavonga	0.0232	0.89	6.02	20,112	18	4019	448	154	11.7
Sinazongwe	0.0268	0.90	6.05	23,380	21	4456	471	111	19.0
Solwezi	0.0462	1.67	6.3	55,014	92	11,415	806	719	12.8
Zambezi	0.0288	0.95	7.44	16,805	16	4168	384	124	12.9

deaths that are pregnancy-related (PMFD), PRMR, Births, Deaths and PRMRatio as a check against the main results.

We evaluated the associations between ALTR and two other indicators associated with risk of pregnancy-related deaths, TFR and PMFD, using scatter plots fitted with simple linear regression lines. For the purposes of illustrating the results, we used three districts, Ikelenge district in North Western province, Mongu district in Western province and Lusaka district, the capital of Zambia. Ikelenge was the smallest district in the country at the time of the census. It is a rural district, located at the border between Zambia and Angola to the west, and the Democratic Republic of the Congo to the north, and had a total population of 32,919 (Central Statistical Office 2013). Mongu is the capital of Western province and had a total population of 179,585, one third of which resided in urban areas (Central Statistical Office 2012a). Lusaka is located approximately in the centre of the country, is completely urban and had a total population of 1,747, 152, with a population density of 4853 persons per square kilometre (Central Statistical Office 2012a).

Ethical approval

Our study used information from the 2010 census descriptive tabulations reports published by the Central Statistical Office (CSO) based on the full count of the country (Central Statistical Office 2012b). Use of such aggregated population data summaries, containing no personal identifiers, does not require ethical approval.

Results

A female aged 15 in Zambia at the time of the census in October 2010 had a 3.7 % (1 in 27) chance of dying a pregnancy-related death before the age of 50, taking into account other causes of death among women of reproductive age. At district level, the ALTR ranged from 1.7 % in Gwembe district to 7.7 % in Chilubi district (Table 1). Half of the ten districts with the highest ALTR belonged to one province, Western province, while 40 % of the 10 districts with the lowest ALTR also belonged to one province, Muchinga province. Among the 10 low-risk districts, the ALTR ranged from 1.7 % (1 in 60) to 2.3 % (1 in 44), while among the 10 high-risk districts, the ALTR ranged from 5.8 % (1 in 17) to 7.7 % (1 in 13).

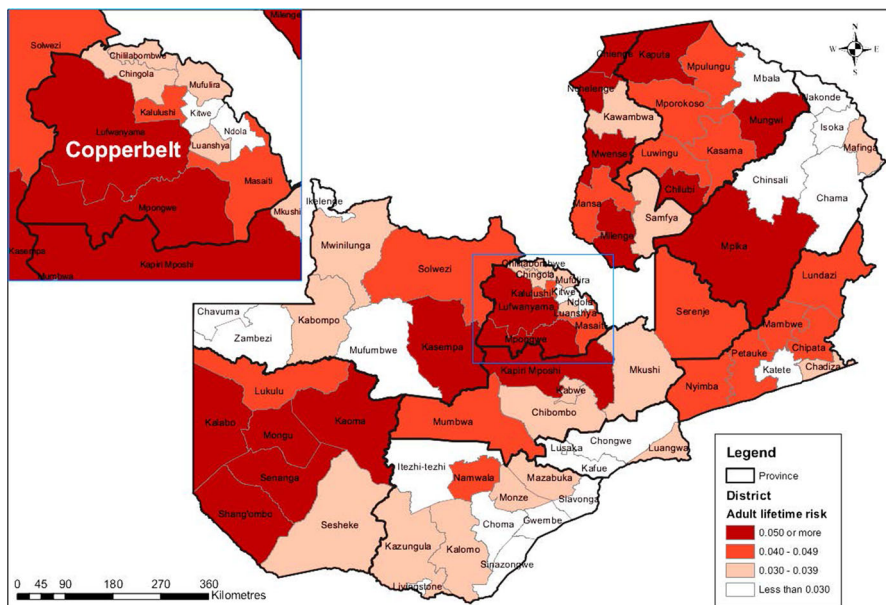
Results of the Global Moran's *I* spatial autocorrelation analysis are summarised in Table 2, and based on the results, the null hypothesis that the ALTR was randomly distributed across the 74 districts must be rejected. The z-score of 5.81 was high enough to indicate that there was clustering of districts with similar levels of ALTR and this was statistically significant at 1 % level of significance.

The clustering of districts is also evident in Fig. 1, which shows the district-level map of Zambia. The highest concentration of districts with very high ALTR was in Western province, where five out of a total of seven districts had an ALTR of 5.8 % (1 in 17) or more. The concentration of low-risk districts was highest in Lusaka

Table 2 Summary of Global Moran's I analysis of spatial clustering of various variables, Zambia 2010 census

	Pregnancy-related deaths	Births	Deaths of women aged 15–49	PMFD	Total fertility rate	PRMRatio	PRMR	Adult lifetime risk
Moran's index	0.0443	0.0597	0.1011	0.2364	0.4092	0.4996	0.4967	0.4521
Expected index	−0.0137	−0.0137	−0.0137	−0.0137	−0.0137	−0.0137	−0.0137	−0.0137
Variance	0.0041	0.0029	0.0031	0.0064	0.0064	0.0064	0.0064	0.0064
z-score	0.9106	1.3570	2.0526	3.1354	5.2855	6.4103	6.3652	5.8060
p-value	0.3625	0.1748	0.0401	0.0017	0.0000	0.0000	0.0000	0.0000

p-value <0.05 indicates significant clustering of districts associated with similar levels of the variable of interest

**Fig. 1** District-level adult lifetime risk (ALTR) of pregnancy-related death per woman, Zambia 2010 census

province where three out of four districts had an ALTR of 2.3 % (1 in 43) or less. In Lusaka province also, the PMFD was less than 10 % in all the four districts.

Figures 2 and 3 show the association between the adult lifetime risk of pregnancy-related death for a female aged 15 in a district and the prevailing level of TFR and PMFD. Using the three districts (highlighted in the figures), results show that the overall association between the TFR and ALTR was positive, but there was

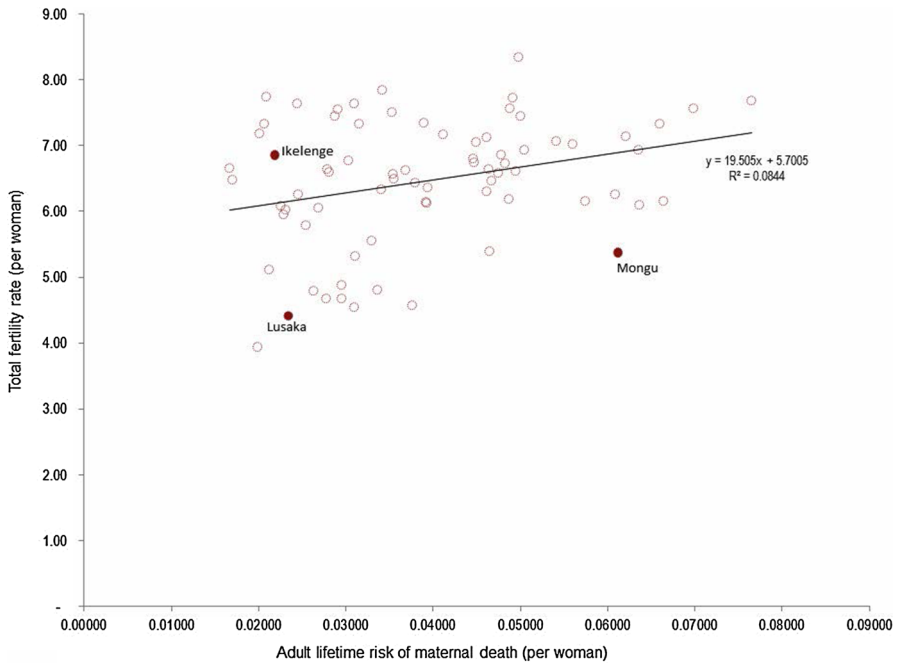


Fig. 2 District level scatterplot of total fertility rate (TFR) and adult lifetime risk (ALTR), Zambia 2010 census

some heterogeneity across districts. For example, women in Ikelenge district had a TFR of 6.86 and an ALTR of 2.2 % compared to women in Lusaka district with a similar level of adult lifetime risk (2.3 %) but lower TFR (4.42) and Mongu district with a TFR of 5.38 (lower than that for Ikelenge district) had an ALTR of 6.1 % (Fig. 2).

Like the TFR, the PMFD was higher for Ikelenge district (18.5 %) compared to 11.3 % for Mongu and 8.3 % for Lusaka districts (Fig. 3), although the district had a lower ALTR.

Discussion

We found significant geographic differences in the lifetime risk of pregnancy-related death among females aged 15 across the 74 districts of Zambia at the time of the census in October 2010. Overall, 3.7 % of females aged 15 would die a pregnancy-related death before age 50. At district level, the risk ranged from 1.7 % in the district with lowest risk (Gwembe) to 7.7 % in the district with the highest risk (Chilubi). Our results revealed patterns of clustering of districts with similar levels of pregnancy-related mortality risk. We found clustering of low-risk districts in Lusaka, Muchinga, Copperbelt, North Western and Southern provinces, and clustering of high-risk districts in Western and Luapula provinces. The lifetime risk

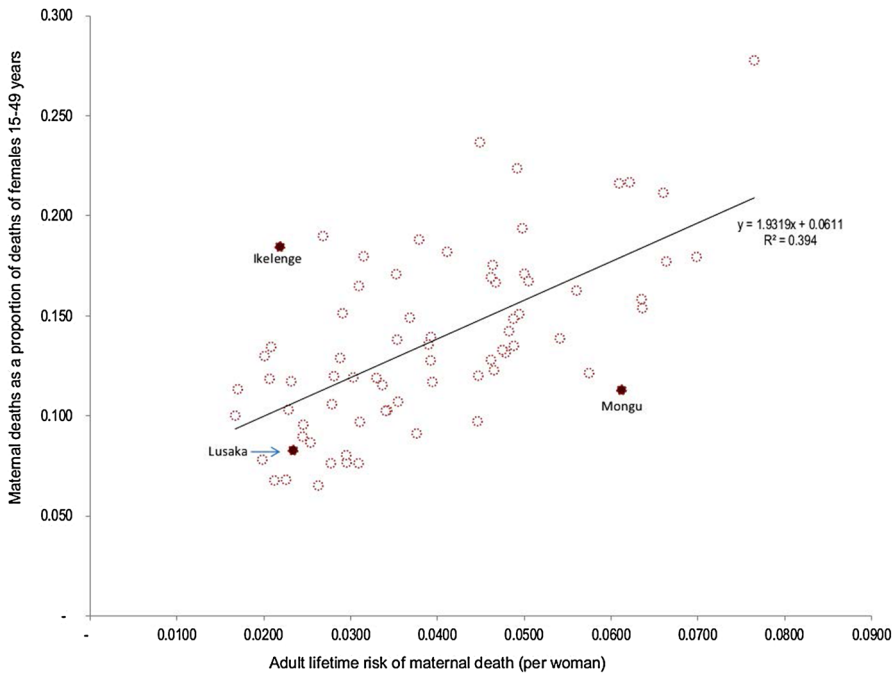


Fig. 3 District-level scatterplot of proportion of female deaths that were pregnancy-related (PMFD) and adult lifetime risk (ALTR), Zambia 2010 census

of pregnancy-related death was weakly positively associated with the district's level of fertility and more strongly positively associated with the proportion of deaths that were pregnancy-related.

The concentration of high-risk districts in Western and Luapula provinces could be partly associated with the level of development and household poverty in the two provinces. Several rounds of the national Living Conditions Monitoring Surveys (LCMS) have consistently shown the two provinces to be the least developed, with the highest levels of poverty among households (Central Statistical Office 2011). The two provinces are also predominantly rural; more than 85 % of the population in Western province and over 80 % in Luapula province reside in rural areas (Central Statistical Office 2012a). There was also clustering of high-risk districts along the borders between the Copperbelt, Central and North-Western provinces (i.e. Lufwanyama, Mpongwe, Kapiri Mposhi and Kasempa districts). About 60 % of districts with ALTR greater than the national average were predominantly rural (>85 % of the population residing in rural areas). Access to health services remains a challenge for most rural populations in Zambia. Most rural health centres cannot provide basic emergency obstetric care because they are lacking the required number of appropriately skilled health care workers, supplies and equipment (Gabrysch et al. 2011; Kyei et al. 2012; Levine et al. 2008; Stekelenburg et al. 2004). Women living in rural areas are therefore more exposed to the risk of pregnancy-related death due to relatively poor access to health services. For

example only 32 % of women in Zambia deliver in health facilities in rural areas compared to 84 % in urban areas (Central Statistical Office et al. 2009).

Although teenage childbearing and marriages are common in most parts of Zambia, the problem is bigger in Western province. Data from three rounds of the Demographic and Health Survey (DHS) conducted between 2001 and 2014 show that 40–44 % of adolescent females aged 15–19 in Western province are already mothers or pregnant with their first child at the time of the survey, which is a higher percentage than in most of the other Zambian provinces (Central Statistical Office et al. 2003, 2009, 2014). In addition, a much earlier study (from 1994 to 1995) in four of the six districts in Western province showed extremely high levels of illegally induced abortions at the time, with an estimated induced abortion mortality ratio of 120 induced abortion-related deaths per hundred thousand live births overall (Koster-Oyekan 1998). Complications of abortion are a major direct cause of maternal morbidity and mortality among adolescent females in Zambia (Castle 1990; Nsemukila et al. 1998). Although the country has had an abortion law since 1972 (Termination of Pregnancy Act 1972), access to abortion services is highly centralised, available mainly in public hospitals and greatly restricted on medical, social or economic grounds and by bureaucratic requirements (e.g. consensus needed from three physicians) (Castle et al. 1990).

The high concentration of low-risk districts in Lusaka province is probably tied to better access to health facilities and services. Overall 78 % of women surveyed in the 2007 DHS in the province delivered in health facilities, assisted by a skilled health provider (Central Statistical Office et al. 2009). The four low-risk districts are in very close proximity to each other and to the capital city Lusaka, and therefore adequately linked by a good road network and transport services. The province also has the highest concentration of health workers (Ferrinho et al. 2011).

The observed geographic diversity and clustering goes beyond the mere spatial distribution of districts, and cannot be explained purely by differences between rural and urban population distributions within districts or provinces. Instead, access to health care services and quality of health care services, which are both linked to the socio-economic development of a region, seems important. This is linked to the three delays theory by Thaddeus and Maine (1994): the risk of pregnancy-related mortality is influenced by the complex interaction of determinants that might culminate in delay in deciding to seek care, delay in reaching a health facility, and delay in receiving quality care. These delays operate at the individual level, the community level, and the health facility level. Next to the role of socio-economic development and health system determinants, cultural determinants are important as well in the decision to seek care, whereas geographic determinants are important as well in the delay in reaching a health facility. These determinants go beyond rural–urban differences.

Whereas high fertility is frequently mentioned as an important determinant of high (risks of) pregnancy-related mortality (Campbell and Graham 2006; Ronsmans et al. 2006; World Health Organisation 2005), our analysis found a positive but rather weak association between the ALTR and TFR across the 74 districts. Actually, high fertility occurred in all districts (all but one district had TFR > 4 per woman), and in some districts, the association between the ALTR and TFR did not

conform at all to the expected pattern of high fertility and high risk of pregnancy-related death. For example the three districts Mbala, Chinsali and Chama were among those with the lowest lifetime risk but also among the districts with very high fertility (TFR > 7 children per woman). It is worth noting that the level of fertility serves as an indicator of the level of obstetric risk in a population particularly when childbirth starts too early, too many births occur too close to each other and when births occur late in the reproductive years (Campbell and Graham 2006; Ronsmans et al. 2006; World Health Organisation 2005). Thus if more births occur to low-risk women aged 20–34 as opposed to high-risk groups of women aged less than 20 and over 35, the risk could be low despite the high fertility. This might be—at least partly—the case for the above-mentioned districts with high TFR and low ALTR.

The positive association of ALTR with the proportion of pregnancy-related deaths (PMFD) was stronger than that between ALTR and TFR. But, as was the case with the TFR, the PMFD was high in some districts where the lifetime risk of a pregnancy-related death was low. For example Ikelenge district had a higher PMFD (18.5 %) but much lower ALTR compared to Mongu district with a high ALTR but low PMFD (11.3 %). A possible explanation could lie in the level of all-cause mortality prevailing in the two districts. Despite the high proportion of female deaths being pregnancy-related in Ikelenge district, all-cause mortality was lower in Ikelenge district than in Mongu district and could have partly contributed to the lower ALTR, as survival to age 15 and subsequent age groups in the reproductive age group 15–49 was higher for females in Ikelenge district than in Mongu district. The low all-cause mortality in Ikelenge district could be partly a result of the relatively low HIV prevalence in particular rural parts of the North Western province (Central Statistical Office et al. 2003, 2009, 2014). Although the geographical differentials in the prevalence of diseases such as malaria, HIV and PTB could partly explain the observed differentials in the lifetime risk of dying a pregnancy-related death, lack of data on disease burden at district level made it a challenge for us to make any meaningful conclusion or attribution to any such diseases.

Our estimates of lifetime risk of pregnancy-related death are likely to overstate the actual risk of dying a maternal death, since pregnancy-related deaths include both maternal and non-maternal deaths. Therefore, interpretation and use of these estimates must make consideration of that fact. Further, our study used only one data source (2010 census data) to analyse lifetime risk of pregnancy-related deaths at district level and therefore could not accurately attribute the observed levels and patterns to direct determinants of risk such as contraceptive prevalence (Stover and Ross 2010), proportion of facility deliveries or skilled attendance at birth (Campbell and Graham 2006) in each of the districts, among other factors. Reporting bias in both overall deaths and pregnancy-related deaths could also have affected the estimates. Misclassification of pregnancy-related deaths is a likely source of error by households reporting deaths of reproductive-age women (World Health Organisation et al. 2014). Deaths of women in the early stages of pregnancy are less likely to be reported as pregnancy-related deaths, while deaths resulting from complications of abortion might be underreported or omitted due to stigma. A study at Zambia's highest national referral hospital in Lusaka found that 44 % of pregnancy-related

deaths were due to non-obstetric causes, among them, malaria and tuberculosis (Ahmed et al. 1999). Such deaths would therefore also be misclassified and misreported by households in a census. A challenge in evaluating and adjusting maternal or pregnancy-related deaths reported in censuses is the lack of methods for making such evaluations and adjustments, and this has been noted by several other studies based on census data (Hill et al. 2009, 2010; Stanton et al. 2001). Improvements in reporting by households, as well as development of evaluation and adjustment methods, could lead to more robust estimates in the future. Given the scope of the census, reporting errors are likely to be random rather than systematic across districts. Standard training curriculum and instructions were given to all census enumerators in all districts, and interviews were conducted using the same questionnaires. Some bias could have arisen from the translation of questions from the English questionnaire into the local language of the district, but is likely to be minor since questionnaire translation was part of the standard training curriculum. Age misreporting and misreporting of deaths and births are common in censuses across developing countries, partly due to the high proportion of illiterate people, but even such errors when measured at district level tend to be random, rather than systematic. Therefore any errors are likely to be spread across all districts and not likely to affect district comparisons. Our study thus provides plausible estimates of lifetime risk of pregnancy-related death and its geographical distribution at district level in Zambia.

Conclusions

Females in Zambia have a high lifetime risk of pregnancy-related death overall but this risk varies greatly across the different districts of the country. The observed diversity is larger than when merely studying differences between provinces and is only weakly linked to differences in fertility levels. The observed clustering of districts around similar lifetime risk levels cannot be explained by rural–urban differences alone. Instead, differences in the level of socio-economic development among districts, especially linked to the delivery of health services, seem important. Access to and quality of health services available (especially maternal health services), both of which are linked to the socio-economic development of a region, are key in reducing the lifetime risk of pregnancy-related death. Geographical studies that go beyond the rural–urban differences and the province level allow the recognition of districts with varying levels of risk. Our analysis has identified seventeen districts where improved access to high-quality maternal health services seems to be particularly urgent.

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Appendix

See Fig. 4.

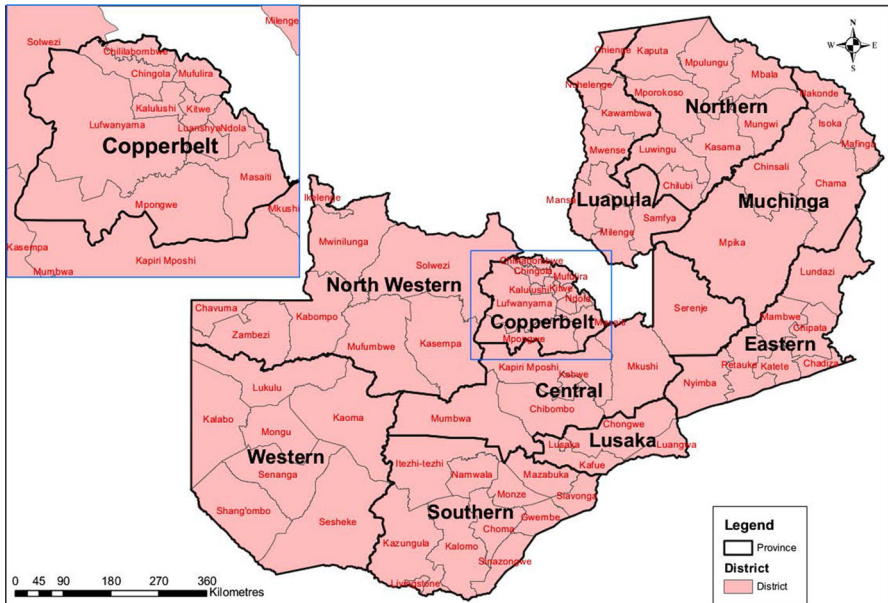


Fig. 4 Map of Zambia showing provincial and district boundaries

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